

**Unsettled Issues
Concerning Integrated
Vehicle Health
Management Systems
and Maintenance Credits**

Ravi Rajamani

Unsettled Issues Concerning Integrated Vehicle Health Management Systems and Maintenance Credits

Ravi Rajamani, PhD
Principal Consultant, drR2 consulting

EDGE DEVELOPMENT TEAM

Bal Annigeri, *Pratt & Whitney (Retired)*

Mark Davis, *Sikorsky (Retired)*

Bill Heliker, *Federal Aviation Administration*

Ian Jennions, *Cranfield University*

Marcus Labay, *Federal Aviation
Administration*

David Piotrowski, *Delta Air Lines*

Pierre-Charles Rolland, *Airbus*

Guilherme Torres, *Embraer*

Rhonda Walthall, *Collins Aerospace*





About the Publisher

SAE International® is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries. Our core competencies are lifelong learning and voluntary consensus standards development. Visit sae.org

SAE EDGE™ Research Report Disclaimer

SAE EDGE™ Research Reports focus on topics that are dynamic, in which knowledge is incomplete, and which have yet to be standardized. They represent the collective wisdom of a group of experts and serve as a practical guide to the reader in understanding unsettled subject matter. They are not meant to provide a recommended practice or protocol. The experts engaged have contributed their own thoughts and points of view, and these are not the positions of the institutions or businesses with which they are affiliated. A professional writer has collectivized their input; there is no one contributor's perspective being advanced but rather that of a community of practitioners. SAE EDGE™ Research Reports are the property of SAE International, and SAE alone is responsible for their content.

About This Publication

SAE EDGE™ Research Reports provide state-of-the-art and state-of-the-industry examinations of the most significant topics in mobility engineering. SAE EDGE™ contributors are experts from research, academia, and industry who have come together to explore and define the most critical advancements, challenges, and future direction in areas such as vehicle automation, unmanned aircraft, Internet of Things and connectivity, cybersecurity, advanced propulsion, and advanced manufacturing.

Related Resources

SAE MOBILUS® Automated & Connected Knowledge Hub
<https://saemobilus.sae.org/automated-connected/>

SAE Team

Frank Menchaca, Chief Product Officer
Michael Thompson, Director, Standards, Information, and Research Publications
Monica Nogueira, Acquisitions Director
Beth Ellen Dibeler, Product Manager
William Kucinski, Managing Technical Editor

Copyright © 2020 SAE International. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system, distributed, or transmitted, in any form or by any means without the prior written permission of SAE International. For permission and licensing requests, contact SAE Permissions, 400 Commonwealth Drive, Warrendale, PA 15096-0001 USA; e-mail: copyright@sae.org; phone: 724-772-4028; fax: 724-772-9765.

Printed in USA

Information contained in this work has been obtained by SAE International from sources believed to be reliable. However, neither SAE International nor its authors guarantee the accuracy or completeness of any information published herein and neither SAE International nor its authors shall be responsible for any errors, omissions, or damages arising out of use of this information. This work is published with the understanding that SAE International and its authors are supplying information, but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

EPR2020006

ISSN 2640-3536

e-ISSN 2640-3544

ISBN 978-1-4686-0183-1

To purchase bulk quantities, please contact: SAE Customer Service

E-mail: CustomerService@sae.org

Phone: 877-606-7323 (*inside USA and Canada*)
724-776-4970 (*outside USA*)

Fax: 724-776-0790

<https://www.sae.org/publications/edge-research-reports>

About the Editor



Dr. Ravi Rajamani is an independent consultant in the aerospace and energy sectors. He has many years of experience in the application of systems engineering principles and data analytics and model-based methods to controls, diagnostics, and prognostics, especially for propulsion systems. He has authored or coauthored five books, including *Electric Flight Technology: The Unfolding of a New Future*. In addition, Dr. Rajamani is the author of many book chapters, journal articles, conference papers, and patents. Prior to his current job, Ravi worked at Meggitt, United Technologies Corporation, and the General Electric Company. He has a PhD from the University of Minnesota and an MBA from the University of Connecticut. His earlier degrees were BTech from the Indian Institute of Technology, Delhi, and an MSc from the Indian Institute of Science, Bangalore. He is active within various SAE technical committees dealing with prognostics and health management (PHM) and electric propulsion. He is also active in the PHM Society, serving on its board of directors. He has been elected as Fellow of SAE International and of the Institution of Mechanical Engineers. He currently serves as the Editor-in-Chief of the SAE International Journal of Aerospace. In addition, he has a research appointment at the University of Connecticut and is a visiting Professor at Cranfield University.

contents

About the Editor

Unsettled Issues Concerning Integrated Vehicle Health Management Systems and Maintenance Credits 3

- Introduction 5
- State of the Industry 5*
- Unsettled Issues Concerning IVHM Systems and Maintenance Credits 7*

- Regulations Related to Application of IVHM Systems 7
- AC 43-218 12*
- Recommendations 13*

- The Rotorcraft Experience 14
- Recommendations 17*

Specific IVHM Use Cases and Issues in

- Commercial Aviation 17
- Usage-Based Lifting 18*
- Derated Operations 19*
- Oil Debris Monitoring 20*
- Structural Health Management 21*
- Condition-Based Maintenance 22*
- Recommendations 23*

- Summary/Conclusions 24
- SAE EDGE™ Research Reports 25*
- Recommendations 25*
- Abbreviations/Definitions 26*
- Acknowledgments 26*
- Bibliographic References 27*
- Contact Information 28*

Unsettled Issues Concerning Integrated Vehicle Health Management Systems and Maintenance Credits

Abstract

The “holy grail” for prognostics and health management (PHM) professionals in the aviation sector is to have integrated vehicle health management (IVHM) systems incorporated into standard aircraft maintenance policies. Such a change from current aerospace industry practices would lend credibility to this field by validating its claims of reducing repair and maintenance costs and, hence, the overall cost of ownership of the asset. Ultimately, more widespread use of advanced PHM techniques will have a positive impact on safety and, for some cases, might even allow aircraft designers to reduce the weight of components because the uncertainty associated with estimating their predicted useful life can be reduced. The journey to that end will not be easy, but we believe that it will be successful. The entire idea of diagnostics and prognostics is to look at sensed data along with the knowledge about system operations from accurate models, and develop an estimate of whether the system is behaving in an acceptable manner. Even when operations are within a range of acceptable behavior, IVHM systems can predict future behavior of the systems from estimated deviations and trends. For example, vibration levels in an engine might be acceptable within engineering limits of operation but might start trending consistently in the “wrong” direction. Using this information to predict the condition of the engine in the future would constitute a prognostic estimate that can be used to schedule appropriate upcoming maintenance actions. In general, maintenance practices in the aviation world depend on regular inspections to ensure that systems are functioning correctly. These maintenance practices are enhanced by condition indicators that can trigger alarm conditions that require immediate or imminent action. Until quite recently, the use of IVHM systems to either increase inspection intervals or eliminate them in favor of fully condition-based maintenance (CBM) has not been deemed acceptable by regulatory authorities. In this report we will outline a few developments in recent times that point to a more favorable future for IVHM systems in affecting established maintenance

RAVI RAJAMANI, PHD

Principal Consultant, drR2 consulting

Edge Development Team

Bal Annigeri, *Pratt & Whitney (Retired)*
Mark Davis, *Sikorsky (Retired)*
Bill Heliker, *Federal Aviation Administration*
Ian Jennions, *Cranfield University*
Marcus Labay, *Federal Aviation Administration*
David Piotrowski, *Delta Air Lines*
Pierre-Charles Rolland, *Airbus*
Guilherme Torres, *Embraer*
Rhonda Walthall, *Collins Aerospace*

ISSN 2640-3536